What is claimed is:

1 A nonlinear optical and electro-optical material for optical signal processing, spectral and spatial filtering, light amplification or generation comprising

- a frequency bandgap medium exhibiting at least one photonic bandgap forbidden for electromagnetic modes of the light propagating in at least one direction,
- a set of quantum systems including at least one atom, molecule or quantum dot having at least two degenerate or non-degenerate discrete energy levels with at least one working transition between the energy levels interacting with the light,

wherein said set of quantum systems is embedded into said frequency bandgap medium, and frequency of said at least one working transitions between the energy levels of the quantum systems lies inside the said photonic gap of the frequency bandgap medium developing a phonic passband inside the photonic bandgap and ensuring efficient suppression of spontaneous decay of the upper energy state of the working transition.

2. An active optical material for light amplification and lasing of Claim 1, wherein the developed photonic passband is chosen such to achieve the rate of radiation decay of the excited state of the working transition required for creation of efficient inversion of population in the upper energy state of the working transition.

3. A device for optical signal processing, transmission or generation comprising

- at least one input optical signal port;
- at least one output optical signal port;
- at least one optional control port;

- a set of quantum systems including at least one atom, molecule or quantum dot having at least two degenerate or non-degenerate discrete energy levels with at least one working transition between the energy levels interacting with the optical signals;
- a frequency bandgap medium exhibiting at least one photonic bandgap forbidden for electromagnetic modes of the optical signal propagating in at least one direction,

wherein said set of quantum systems is embedded into said frequency bandgap medium, and frequency of said at least one working transitions between the energy levels of the quantum systems lies inside the said photonic bandgap of the frequency bandgap medium developing a phonic passband inside the photonic bandgap and ensuring efficient suppression of spontaneous decay of the upper energy state of the working transition.

4. A device for optical signal processing, transmission or generation of Claim 3, comprising a wire-like spatially ordered or disordered structure of the quantum systems forming a quantum system waveguide.

5. A device for optical signal processing, transmission or generation of Claim 3, wherein said quantum systems comprise of either semiconductor quantum dots having confined conduction band energy level and confined valence band energy level, and each of said at least two confined energy levels are capable of being populated with at least one charge carrier or metal quantum dots having at least two confined energy levels due to geometrical quantization.

6. A quantum system waveguide of Claim 4, comprising a chain of close packed core-shell quantum dots each having the quantum dot core surrounded with a shell made from another optical material transparent in the vicinity of the working

transition of the core quantum dot, such as a polymer or a semiconductor with wider bandgap, wherein core diameter of the core-shell quantum dot determines the energy level structure of the quantum dot, while the diameter of the shell determines interdot spacing and hence the spatial period of the quantum dot chain waveguide.

7. A device for optical signal processing, transmission or generation of Claim 3, wherein the photonic bandgap medium is an artificial photonic crystal, in which the density of propagating radiation modes in the vicinity of working transition is essentially suppressed in at least one of the directions of light propagation.

8. A device for optical signal processing, transmission or generation of Claim 3, wherein the photonic bandgap medium is an ionic crystal, a molecular crystal, a semiconductor material, or any other optical material exhibiting a gapped or pseudo-gapped frequency spectrum of elementary electromagnetic excitations, in which the density of propagating radiation modes in the vicinity of working transition is essentially suppressed in at least one of the directions of light propagation.

9. A quantum system waveguide of Claim 4 operating as a line of delay of optical pulses, wherein spacing between quantum systems is chosen such to provide the required group velocity of passband light pulses propagating along the quantum system waveguide.

10. A quantum system waveguide of Claim 4 performing the functions of all-optical switch, modulator, transistor or control-NOT logic gate, wherein optical signal in said at least one control port changes population of the discrete energy levels of the working transition in at least one of the quantum systems of the

quantum system waveguide to control the optical signals propagating along the waveguide.

11. A quantum system waveguide of Claim 4 performing the functions an electro-optical switch, modulator, transistor, control-NOT logic gate or converter of electrical signals into light signals, wherein an electrical control signal in said at least one control port is applied to at least one of the quantum systems of the quantum system waveguide changing frequency of the working transition of the quantum system due to shift of energy levels in the quantum system (Stark effect) to control the optical signals propagating along the waveguide.

12. A nonlinear directional coupler comprising at least two quantum system waveguides of Claim 4, wherein separation between said quantum system waveguides and intensities of the input optical signals are selected such to ensure the required coupling between signals propagating in the quantum signal waveguides, splitting of the input signal between the quantum system waveguides or coupling of the propagating signals from one quantum system waveguide to another.

13. A device for optical signal processing, transmission or generation of Claim 3, wherein optical signals are coherent light pulses that are chosen to be much shorter than the characteristic dephasing time of the working transitions in the quantum systems embedded in the photonic bandgap medium in order to perform quantum optical signal processing.

14. An optical switch, modulator, or transistor of Claim 10, wherein optical signals are coherent light pulses that are chosen to be much shorter than the characteristic dephasing time of the working transitions in the quantum systems

embedded in the photonic bandgap medium in order to perform quantum optical signal processing.

15. An optical switch, modulator, or transistor of Claim 11, wherein optical signals are coherent light pulses that are chosen to be much shorter than the characteristic dephasing time of the working transitions in the quantum systems embedded in the photonic bandgap medium in order to perform quantum optical signal processing.

16. A nonlinear directional coupler of Claim 12, wherein optical signals are coherent light pulses that are chosen to be much shorter than the characteristic dephasing time of the working transitions in the quantum systems embedded in the photonic bandgap medium in order to perform quantum optical signal processing.

17. A nonlinear directional coupler of Claim 12 performing functions of a generator of entangled states of photons, wherein optical signals are coherent light pulses that are chosen to be much shorter than the characteristic dephasing time of the working transitions in the quantum systems embedded in the photonic bandgap medium.

18. A generator of entangled states of photons of Claim 17, wherein input light signals in the quantum nonlinear directional coupler have different polarizations to generate the photons entangled in polarization.

19. An optical amplifier based on the quantum system waveguide of Claim 4, wherein said at least one quantum system waveguide is pumped either electrically or optically to create inversion of population, and the light signal propagating in

the pumped quantum system waveguide is amplified due to stimulated emission of excitations of the quantum systems into passband photons of the quantum system waveguide.

20. A laser based on the quantum system waveguide of Claim 4, wherein said input optical signal port is absent, the quantum system waveguide is pumped either electrically or optically to create inversion of population, the light signal propagating in the pumped quantum system waveguide is amplified due to stimulated emission of excitations of the quantum systems into passband photons of the quantum system waveguide, and the quantum system waveguide has a means creating a feedback for the passband photons resulting in generation of coherent light.